CubeSat Communications Research Competes in NASA iTech

Ehrlich, Michael; Imbukwa, Khaboshi

Monterey, California. Naval Postgraduate School

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Research into how small satellites, known as CubeSats, communicate with each other and the Earth performed by a team of researchers in the Naval Postgraduate School's (NPS) Space Systems Academic Group (SSAG) was one of 10 innovations selected to participate in NASA iTech's Cycle Two competition at Langley Research Center. SSAG Research Associate and Ph.D. student Giovanni Minelli, along with Research Associate Professor Mark Karpenko, Professor Mike Ross and SSAG Chair Jim Newman, comprise a group of investigators looking to build autonomy into the communications of low-earth's ever increasing number of orbiting spacecraft.

The NASA iTech competition, hosted by the Office of the Chief Technologist at NASA, provides a forum for the broader research community to bring new, innovative ideas forward ... Ideas that not only advance varied elements of society and industry, but can also be leveraged to solve NASA's space technology challenges.

“We were judged on two criteria,” explained Minelli. “One is how relevant are we to NASA’s goals of exploration; the second is how can this technology flow into the industry for uses outside of NASA’s interests.

“For me, it is very gratifying to have worked on this topic for about five years and finally have some results that I can share with the greater community,” Minelli continued. “I knew I chose a research topic that, at the end of the day, is valuable to our nation’s space program. What was also encouraging was not just competing but hearing from these judges. We got a lot of feedback on how we can make our research better and even more relevant.”

CubeSats are miniature satellites that have been growing in use over the last decade. NPS boasts a lengthy history of success with the small spacecraft, recognizing the value of the platform from an educational perspective early on.

“NPS’ role in small satellites serves two purposes. First and foremost is the educational piece, we want to be able to provide a hands-on education for our officers here in SSAG, specifically in building small satellites quickly, launching them and operating them,” described Minelli. “That gives our students a chance to be a part of that life cycle, in the very short time period they are here, before they go back out to the military.”

CubeSats’ popularity has grown significantly over the past decade. Their low cost to build and deploy makes them particularly desirable, although their small stature creates problems and limitations to their capabilities compared to traditional satellites.

“The reason for their growth is because the price point makes them more attractive for certain missions, rather than spending a lot more money on a bigger satellite you might not need,” said Minelli. “That also translates to the ground stations where you might not need to spend tens of millions of dollars on pristine ground stations. You might be able to spend tens of thousands of dollars and get away with maybe not as good of a capability, but good enough to still communicate effectively with your satellites.”

This is not to say that CubeSats aren’t creating new capabilities. Through sheer volume, large quantities of CubeSats, coined constellations, can canvas larger swaths of the sky to allow for new potential in mission development.

“We just had a phone call with NASA last week about how to integrate our research into their ground station networks because they are building and launching many small satellites in the next few years … CubeSats are a huge piece of their exploration portfolio,” said Minelli, “If there is a way to lower the costs for these mission operations, for these large constellations of small CubeSats, for NASA and the DoD, this is the whole point of doing this kind of research.”

Minelli’s Ph.D. research is attempting to create an infrastructure for CubeSats and ground communication networks. Regardless of who launches the CubeSats – NASA, DOD, private industry, academia – the infrastructure maintains communication capabilities, regardless of the origin of the spacecraft.

Newman, Ross and Karpenko are leading members of NPS’ SSAG, highly-regarded in their respective fields, and represent Minelli’s Ph.D. committee. Karpenko specifically works in the Control and Optimization Laboratories where the primary research goals are to create optimization algorithms that result in the most efficient movement, or ‘slewing,’ of satellites in orbit.

“The scale of the problem that Gio is attempting to address is unprecedented,” said Karpenko. “The current tools and techniques to attempt to find a solution to this problem are inadequate as they are not able to scale gracefully to

the size of constellations that he is looking at in his research.

“As a result of that, he is looking to apply some of the new techniques and tools developed at NPS to attempt to address this problem. He is looking to find a solution that will scale gracefully as the number of satellites increase and the ground networks become more and more constrained,” Karpenko continued.

Minelli forecasts that thousands of these types of satellites will be launched in the next handful of years. He explains how the problem of communication between satellites and ground stations is better solved before it occurs.

“The reason why we are looking at this from this angle is that, over the past 10 years, you would see folks build satellites around the government for their own experiments and their own ground station to go with the satellite,” explained Minelli. “And when they launch these missions, for the most part they would be successful. But when you look around the government, with a lot of people doing kind of the same the thing, the ground stations looked very similar, the satellites looked pretty similar, but nothing was interconnected.

“From a research and development point of view, that was fine in early development because people were still trying to decide if the small sat form was even a viable platform for research. That has shown to be true, but now we can’t scale that up without working together,” he continued. “One of our efforts here is to bring together all these different folks from around the government and provide a common piece of infrastructure in the form of a ground station network that they can leverage.”

The commonalities that Minelli is instituting in his work relate to frequencies and antennas. He hopes to expedite the process of licensing CubeSats, since he estimates that it only takes six months to build a CubeSat, but two years to license it.

“I think Giovanni was one of the finalists this particular round because the ideas that are imbedded in his thesis have the potential to fundamentally change how people look at planning and allocation for very large scale systems,” said Karpenko. “Some of the ideas he is working on are obviously related to communication with to satellite constellations, but they can be applied across a very wide spectrum, from autonomous vehicles to constellations of unmanned aerial vehicles. I think that some of those concepts appeal to other sectors of industries.”

Minelli believes that NPS’ opportunity to test with real satellites and ground stations was one of the discerning differences between his team and other competitors.

“We went from the drawing board to real implementation in just a few years. Now the key is what else can we do? How can we make the models more complex? How do we better reflect reality? How do we make it more applicable to make it more desirable,” Minelli said.

Minelli came to NPS from NASA’s Ames Research Center in California, where he worked on some of the agency’s earliest CubeSat research. Now years into his time at NPS, he recognized some striking differences between the two organizations.

“One of my first impressions was how well connected NPS laboratories were, and how relevant the research was,” said Minelli. “We’re able to work with all different folks all over the government and all branches of the military, various universities, private contractors, all these stakeholders from around the DOD and industry. I don’t think we would have the opportunity anywhere else other than NPS which helps make the research the most relevant.

“But in the end, it all comes back to the education,” he continued. “Why we do what we do is to make the research

more relevant for our students. We take on challenging problems to keep ourselves sharp. When the students come to NPS, they come to learn about new technologies, and new approaches. By keeping this research here at NPS, we make the education as relevant as possible for our students."